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GEOLOGICAL SETTING OF NEW MEXICO

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The unique distinction which New Mexico holds in American geology is that it is the meeting-point of four major and diverse geographic provinces. Together these four provinces embraces nine-tenths of the North American continent. Effects of general land depletion under widely different climatic conditions are thus rarely so strongly contrasted.

Situated well within the boundaries of the vast southwestern desert, the operations of the epicene geologic processes are rendered the more conspicuous because of the fact that they are so very different from those of the pluvial eastern parts of the country with which most of us are most familiar.

New Mexico is distinctly a mountainous country. Its orogeny, however, is chiefly erosional rather than tectonic. Relief of the area is characteristically that of a land of little rain. Facial expression of the region is clearly not stream-corraded but wind-abraded. Owing to the fact that the wind sweeps up its chips as fast as it cuts them the magnitude of eolic erosion is at first difficult to measure with any great degree of satisfaction. Except under especially favorable conditions definite figures cannot always be given. Only when a desert chances to have, somewhere within its boundaries, remnants of old peneplains highly uplifted may the extent of regional depletion be closely estimated. As do moist lands under the influences of stream activities, so arid regions soon develop strong contrasts of surface relief under wind scour. Belts of weak rocks are soonest worn down, leaving the hard rock masses protruding as mountains

In a region of uniform flat-lying strata the relief contrasts are not always marked. When, however, there are rock beds of great thickness, alternating hard and soft members, with close-patterned mountain structures as in the arid lands of western United States, differential relief effects attain maximum extremes. In this tract it is that the seeming youthfulness of the lofty desert mountains is at once impressed with amazing vividness upon the mind of the observer fresh from his pluvial homeland.

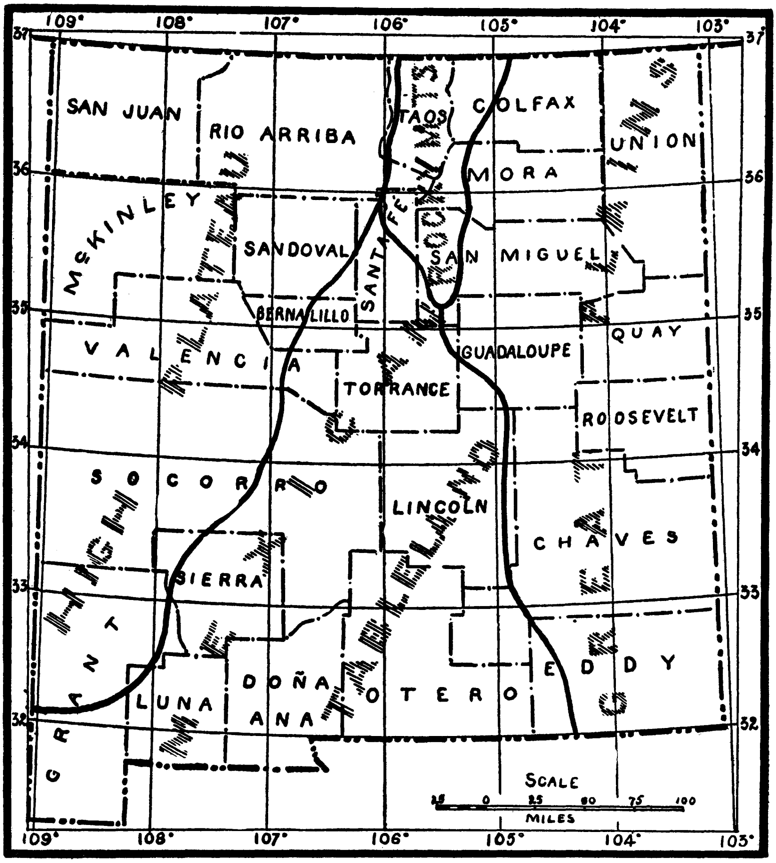

FIG. 1.—Physiographic regions of New Mexico

Once clearly discriminated, wind-graved relief expression is seldom mistaken for any other kind. Its individuality is very strong. Wind-beveled surfaces are smoother than water-formed plains possibly can be. The rock floors which characterize so many desert plains are phenomena as novel as they are unexpected.

Desert ranges rising abruptly out of the plains about impart characteristic form to the enisled landscape. The girdled mountain attests the vigor of natural sand-blast action; and its maximum effectiveness is at the plains line. Plateau plains of the desert manifestly represent former levels of the general plains surface. The notable absence of foothills around the mountain bases appears to be an idiosyncrasy of arid lands.

Arid planatation takes place uphill as well as down; antigravitational gradation is unknown where streams erode. High gradients of the intermontane plains and strong pitch of valley axes which are displayed on every hand are not possible in regions where water action is directly the reverse of plains forming. Of minor features attributable to wind abrasion in the lands of little rain, there are a multitude that have been ascribed to normal water corrasion but that are now known never to have been touched by stream. Upon all of these the wind marks when once pointed out are unmistakable.

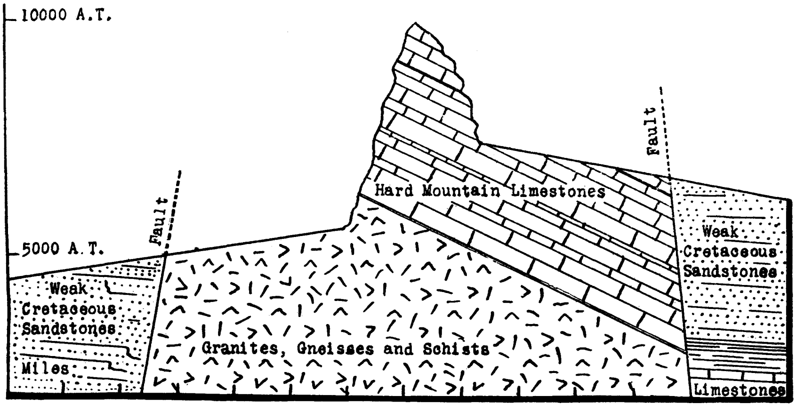
10000 A.T.
5000 A. T.
Fault
Fault
Hard Mountain Limestones
Weak Cretaceous Sandstones
Miles
Granites, Gneisses and Schists
Weak Cretaceous Sandstones
Limestones

FIG. 2.—Sierra de los Caballos: origin of enisled relief

It so happens that the broad arid tract of southwestern United States has within its borders abundant traces of former base-level plains, one of which peneplains is now raised more than two miles above sea-level. The attainment of its present position is regarded as having taken place in late Tertiary times. This great peneplain no doubt once extended over all of this desert region, at a level somewhat above the tops of the present mountains. Inasmuch as desert conditions began to set in about the same time, there is every reason to believe that the magnitude of the general land depletion is represented by the difference between this old peneplain level and the present plains level—an interval of between 5,000 and 6,000 feet—or something over one mile of thickness, over an area equal to nearly one-quarter of that of the entire United States.

There are many considerations supporting the assumption that this area was before recent uplift a vast plain rather than a mountainous tract when arid climate was inaugurated. Inappreciable aid from stream corrasion in this prodigious regional depletion is indicated by the very fact of the prevalence of aridity itself. This region is one of the best extant, demonstrating beyond peradventure the almost boundless potency of the wind as an epicene power in re-forming the face of earth.

For general purposes of earth study no part of our land is so favored as New Mexico. More diverse phenomena are crowded together in limited space than perhaps anywhere else on our globe. Every known category of geologic process appears to be represented. Every known cause of geographic product seems to have been in operation. In great variety and with diagrammatic distinctness of textbook illustration are the larger rock structures displayed. Everything, too, is on such a gigantic scale. Such phenomena as dikes and faults have to be viewed from afar, from distances of miles, in order to get proper perspective of their relations. Orographic features, which are usually assumed to be structural, are found to be mainly erosional.

From the lofty cornice of the Sandias a landscape prospect spreads out a distance equal to that from New York to Chicago. Billows of mountain ridge take on an aspect of choppy sea as viewed from the deck of an ocean liner. The silver thread of the Rio Grande glints in the light of the desert sun for 400 miles until finally lost on the verge of the world—so clear is the dry, thin air of the desert.

The crystalline framework of the region is both varied and substantial. Crystalline schists of the fundamental complex are abundant and of many colors. If he could have viewed them they would surely have gladdened the heart of Johannes Lehmann. Had the grand old pioneer in the field chanced to dwell in this country instead of Saxony the Erzgebirge might never have become so famous; and *Die Untersuchungen über Entstehung der altkrystallinischen Schiefergesteine* might have had the desert range of New Mexico for the central theme of his great epic.

The massive plutonic rocks, the granites, diorites, gabbros, and diabases, cut and intrude the pre-Cambrian complex in all directions. Their surface types appear to have utterly disappeared, probably during the long periods of erosion as indicated by the great unconformities.

Volcanics belong to all ages from the Cretaceous onward. San Mateo is one of the majestic volcanic piles of the continent. It now stands perched high upon a lofty Cretaceous pedestal. A forest of volcanic necks stretches away to the northward. Modern basalt flows cover hundreds of square miles. Older lava streams constitute the resistant cap of many plateau plains. Intrusive sheets run for scores of miles across the plains like great walls of cyclopean masonry. Laccolithes (Fig. 3) display their tectonic origin rather than formation through simple hydrostatic welling. Cinder cones are numerous (Fig. 4). Beside the fine cone of Capulin that of famed Vesuvius sinks into utter insignificance. The phenomena of classic Auvergne and the Phlegræan fields are reproduced again and again but on grander scale.

Stratigraphical succession in New Mexico is instructive to an extraordinary degree. It is, perhaps, the most complete to be found in any state in the Union. Curiously enough, above the pre-Cambrian crystalline complex highly resistant rocks compose the lower half of the geological column; while in strong contrast weak friable beds are segregated in the upper half. With a close-patterned orogeny this disposition has telling effect upon the final relief expression.

The geological column attains an enormous thickness. Archeozoic, Proterozoic, Paleozoic, Mesozoic, and Cenozoic sections are each about 10,000 feet in vertical measurement. Altogether there are 50,000 feet of strata reposing upon the non-clastic Azoics. It is one of the great critical sections of the country. It is in reality the standard succession of the Western continent. It is a rock sequence such as James Hall vainly sought in his lifelong endeavor to establish a standard stratigraphy for the world. It thrice transcends the united sections of Murchison, Sedgwick, and Lonsdale. With the depositional equivalents of its numerous hiatuses

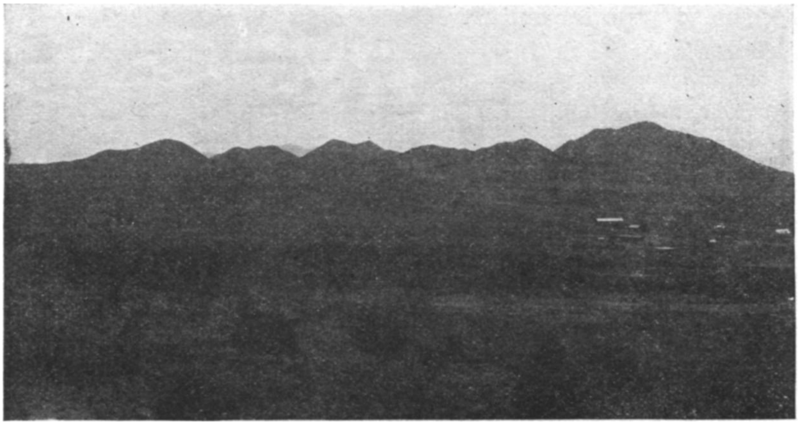

FIG. 3.—Uncovered laccolith of Multiplex Ortiz

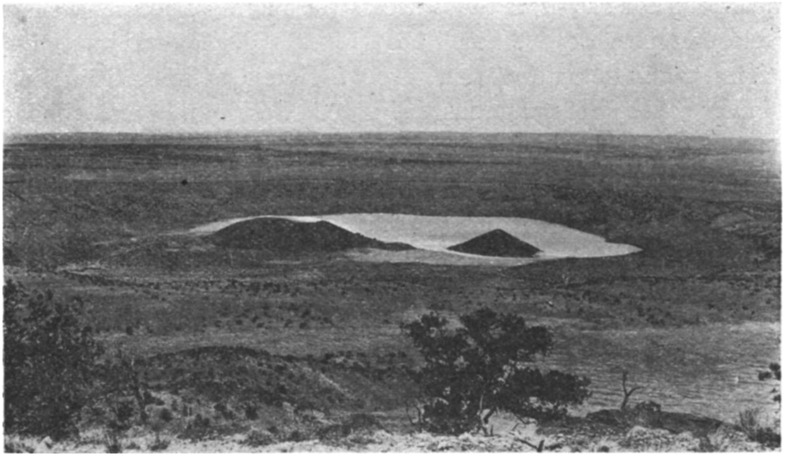

FIG. 4.—Zuni Salt Lake: birth of a volcano. Two cinder cones on floor of explosive crater, 600 feet deep.

it constitutes the longest and best sedimentative record of which we know.

Huge as is the sedimentative prospect, erosive depletion looms up in even vaster proportions. Thirty major unconformities stand for a very much longer interval of time than that which deposition occupied. Nowhere else on the face of the earth does it seem that the stratigraphic record is so clearly defined for a perfectly independent classification of geologic terranes according to diastrophic movement. It is the one place of all where orotaxial principles should sustain themselves under severest test. Any world-scheme of formational arrangement must stand or fall when fitted to this titan among rock sections.

That the pre-Cambrian rocks beyond the southern Rocky Mountains have never received the attention which they really merit recent disclosures amply attest. It seems possible that some day ere long they will divulge as clear a succession as did the transition rocks to English geologists a century ago. At least this is certainly the most promising field for new and large results that the American continent today offers in stratigraphy.

Three grand successions are presented. There is first at the top a thick section composed of relatively slightly metamorphosed and mildly deformed rock masses; then, in the middle, separated above and below, by a great erosional unconformity, a sequence of terranes highly altered, closely flexed, and repeatedly broken through by eruptives of various types; and third, at the bottom, an intensely metamorphosed and sheared complex in which no signs of classic origin are discernible. These grand successions are respectively Proterozic, Archeozoic, and Azoic.

To the Azoic basement are referred all of those lowest pre-Cambrian masses which, intensely altered and profoundly deformed, present no evidence of sedimentary origin. If any such classic character ever existed all trace is now completely obliterated. This intensely metamorphosed complex lying at the very bottom of the exposed rock column is a new find. Its discovery is yet too recent to enable its full significance to be properly evaluated.

Composing this fundamental complex are mainly thinly foliated gneisses, micaceous schists, squeezed granites, and other sheared eruptives. The slightly altered granites, diorites, and diabases which cut the mass are manifestly relatively late intrusives.

Their evident enormous extent, their intensely metamorphosed condition, their extensive deformation, their sharp lithologic contrast with the superior metamorphics, and the marked erosional unconformity dividing the two successions all attest the supreme antiquity of the complex. The depositional equivalent of the summital unconformity may itself surpass in duration the stratigraphic record of the entire Paleozoic section. The best developments of the typical non-clastic Azoics are in the southwestern portions of the state.

The Archeozoic platform is bounded both above and below by marked erosional planes of unconformity. The rocks are all highly metamorphosed. The presence of quartzites, slates, and marbles indicates the clastic origin of a large part of the mass. The section is very thick, possibly not less than two miles.

In marked contrast with the inferior Azoic rocks are the evidences of a clastic origin of the major portion of the section, and a distinct lithologic sequence is plainly discernible. Unconformities which are associated may correspond to those shown in the Grand Canyon, but it is believed that some of the latter are superposed in New Mexico. It is really the Archeozoic rocks chiefly which heretofore have been called Archean, the Azoic masses not being recognized and the Proterozoic segregation not being differentiated.

A thick sequence of pre-Cambrian clastics which are only slightly altered is displayed in the Tijeras Canyon, in the Sandia Range east of Albuquerque, where in a sharp fold a mile of strata outcrops in continuous horizontal section. In discontinuous exposure at least another mile of beds is evidently present. The strata are chiefly shales, locally more or less indurated with some quartzite beds and intrusive granites.

The quartzite beds which stand at high angles are commonly mistaken for immense quartz reefs, and under such misconception they are extensively prospected for gold. Microscopical examination in thin slices demonstrates conclusively that the rock has a clastic origin, and that it is an old sandstone indurated by the interstitial deposition of silica disposed in optical continuity with the separate sand grains. The enormous thickness of the shales is especially noteworthy. It is probable that eventually they will yield an extensive fauna, or a succession of faunas. Should the rock section prove fossiliferous the opportunity for determining faunal sequence would certainly be as favorable as among any Paleozoics of the continent.

Where the crest of the great Tijeras fold of the Proterozoics is deeply beveled off flat-lying limestones of latest Paleozoic age recline directly upon it. This notable unconformity plane represents a period of time of vast duration, one almost coextensive with the Paleozoic era. No less than ten great erosion intervals are superposed one upon another.

Although the early Paleozoic strata are entirely absent over the northern half of New Mexico they are extensively developed in the southern part of the state. There some of the major terranes were identified and correlated with the European sections almost as soon as they were in the Upper Mississippi Valley, or within a decade of the first appearance of Murchison's and Sedgwick's classic works.

When in 1874 undoubted Cambrian beds were first recognized by Jenney in New Mexico only unimportant sandstones were disclosed in the Franklin Mountains north of El Paso. Since that date the extent of the section has been greatly expanded, until now over 1,000 feet of sandstones, quartzites, and limestones are known. Westward these formations connect with the great Cambrian sections of Arizona.

As indicated by the contained fossils both mid- and late-Cambrian sections are fairly well represented, the former by about 700 feet of strata and the latter by 400 feet. There are no evidences of the presence of early Cambrian beds within the borders of the state, and it does not seem likely that any ever will be found.

Ordovician strata were the first Paleozoic rocks recognized within the limits of New Mexico. As early as 1848 Wislizenus recorded the finding of Ordovician (lower Silurian) fossils in rocks west of El Paso. A few years later both Shumard and Antisell discovered similar organic remains in the mountains lying to the north of the same point. The section developed rapidly until it reached a thickness of more than 500 feet, extended entirely across the southern part of the state, and comprised three important series corresponding to the three subdivisions of the period.

These limestones are abundantly fossiliferous. The forms indicate the same sub-periodic divisions that are commonly recognized on the eastern side of the continent. Much of the bottom and top of the general section for the continent is missing in New Mexico. Between the Ordovician beds and the Cambrian below and the Silurian above marked unconformities prevail so that the first-mentioned unit is sharply defined.

Silurian sediments are poorly developed. The rocks out-crop in a thin broken line across the southwestern corner of the state. That deposition during the period was extensive in this region is quite manifest; but it is also evident that during Devonian and Mississippian times the deposits were largely removed through profound erosion. The contained fossils indicate only the Niagaran horizons of the standard eastern section.

From the character of the organic remains the presence of Devonian rocks in New Mexico receives early announcement. Both Antisell and Hall in 1856 call attention to the fossil evidence. Dutton's statement that Devonian strata were generally wanting in the eastern part of the Colorado High Plateau region is somewhat misleading. These rocks are really very much better represented in southwestern New Mexico than has been commonly supposed. In the vicinity of Santa Rita, in Grant County, are 400 feet of light-colored, fine-grained limestones and shales which carry abundant organic remains.

Two parts of Devonian time appear to be represented. The basal shales seem to belong to the mid-Devonian section; while the limestones are late Devonian in age. A surprising feature is that the fauna is the typical Lime Creek phase of northern Iowa. This horizon corresponds to the uppermost part of the section represented in the Upper Mississippi Valley, which is, according to Tschernyschew, Williams, and others, who have given the subject most attention, mid-Devonian in age. These authorities also agree on the appearance of the fauna in the West, or Mississippi Valley region, much earlier than in the East, or New York province; so that, although its age in the first-named locality is strictly mid-Devonian, in the second locality it is late Devonian. This being the case, the same migratory fauna may have put in an appearance in the southwestern or New Mexican province, considerably earlier even than it did in the Upper Mississippi Valley region—possibly in the middle or latter part of early Devonian time.

The Mississippian succession in New Mexico comprises only a limited portion of the middle division of the Mississippi Valley section. Both the upper, or Tennesseean, and the lower, or Waverleyan divisions seem to be entirely missing. Because of its restricted representation and its other notable peculiarities the southwestern sequence is designated the Socorran series. The maximum thickness of these rocks is about 400 feet.

Both the Chouteau and Burlington faunas of the Mississippi Valley are well represented. The list of organic remains is almost as extensive as that of the type localities. Fossils from the Modoc limestone, which extends eastward from Arizona, indicate higher horizons, probably so high as the Keokuk level. Curiously, the huge gastropods which are so rare in the East are very abundant in the Southwest.

The especial importance of the New Mexican section of the Mississippian rocks is that it directly connects the eastern or Ozark sequence with that of the Far West. Summing up the evidence regarding these strata as they are represented around the border of the Colorado High Plateau it appears that there is in the Southeast and South, in southwestern New Mexico and eastern Arizona, the Socorran series; in the West, in northwestern Arizona, the Lower Red Wall formation; in southwestern Colorado the Ouray (upper part) limestone; and east of the southern Rocky Mountains the Millsap limestone. In New Mexico the succession is probably most completely represented and most varied, although perhaps not including all that is represented in Colorado.

In strong contrast with the Pennsylvanian sequence of the middle and eastern portions of the continent the southwestern succession is almost unbrokenly calcareous. A single plate of limestone, which extends over the entire area of the state, reaches far into Texas on the one hand, and on the other hand completely over the Colorado dome to the Grand Canyon, where it appears as the Aubrey limestone, has in New Mexico a thickness of 5,000 feet.

These unbroken limestones are the open-sea analogues of the coastal coal measures of the Mississippi Valley. Where in Iowa they are mainly represented by a great erosional interval, and in Arkansas by 20,000 feet of shore deposits, in the New Mexican field coal-bearing measures are all but completely vanquished. Something of the enormous Arkansan series seems to find expression in the diminutive Ladronesian series with its bare 200 feet of Alamito shales and a scant foot of coal. The last-mentioned formation, which no doubt was once one of very considerable magnitude, is almost effaced through erosion which took place before the laying down of the limestones, which in marked unconformity rest directly upon these shales.

Pennsylvanian, or upper Carboniferous, limestones attain a thickness of 2,000 feet in northern New Mexico. There they recline directly upon the surface of the old pre-Cambrian basement, all else of the Paleozoics being absent. In the South, where they reach a measurement of upward of 5,000 feet and are known as the Hueco succession of limestones, they repose successively upon Mississippian, Devonian, Silurian, Ordovician, and Cambrian formations.

In the North the great limestone plate is best known in the lofty Sandia and Manzano ranges, east of Albuquerque. Throughout this district it appears to be broadly separable into two strongly contrasted formations—a lower shaly and black limestone, and an upper member comprising chiefly massive blue and gray limestones. To the inferior member, 1,000 feet thick, the title "Lunasian series" is given. To the upper sequence, also about 1,000 feet in thickness, the term "Maderan series" seems most appropriate.

On the basis of the determined faunal characteristics the stratigraphical position of the Lunasian series appears to correspond nearly with that of the Missourian series of the Mississippi Valley. Upon the same grounds the Maderan series is paralleled with the Oklahoman series of the eastern field, but which some Kansas workers are prone to correlate with the far-off Permian rocks of the Russian Urals (Fig. 5).

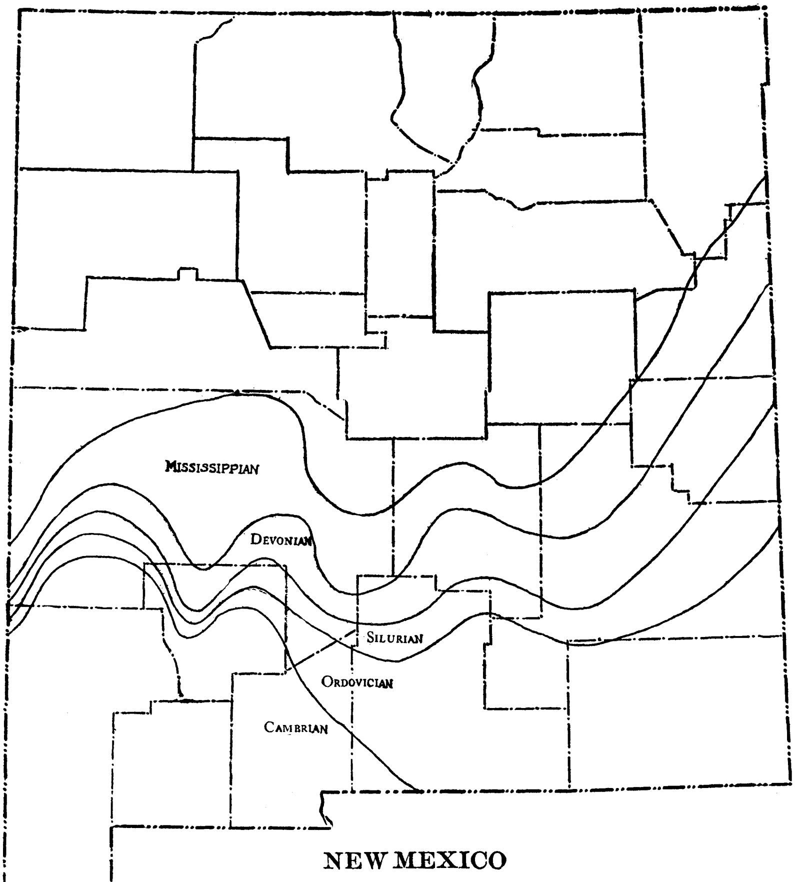

FIG. 5.—Areal range of periodic formations

As Pennsylvanian time was ushered in with the deposition of sands and clays, so also did it close. Succeeding the huge limestone plate is the Bernalillan series of "Red Beds." As first pointed out in 1904[1] the "Red Beds" problem which so long had baffled geologists found a ready solution in the discovery that these deposits were not accumulations of a single geologic age, but, in their different parts, of three distinct ages. Beds of similar lithologic aspect of Pennsylvanian, Permian, and Triassic ages were directly superposed, the normally intervening formations being absent. This was, then, the real explanation why different investigators in different localities had determined such diverse dates for their several sections. Even the unconformity planes were overlooked.

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[1] *Report of the Governor of New Mexico to the Secretary of the Interior for 1903*, p. 339 (Washington, 1904).

The recognition of "Red Beds" of Pennsylvanian age was a distinct advance in the stratigraphy of the Southwest.

It is a curious travesty on the fates that despite the acrimonious controversy which waged for more than a full generation over the possible presence of Permian beds in America, the one section which would have most speedily ended it remained unnoticed, albeit its fossils had long been fully made known. As early as 1860 Shumard described what he distinctly designated a Permian fauna from the Sierra Guadalupe on the New Mexico–Texas boundary; but its true significance remained in complete obscurity for half a century, when Girty accidentally pointed out its global relationships.

Although the Guadalupan succession of sandstones and limestones is nearly 4,000 feet thick at the typical locality the formation rapidly diminishes in force to the northward. Before the Sandias are reached the Bernalillan "Red Beds" and the Cimarronian "Red Beds" are brought together to form an uninterrupted "Red Beds" section.

Cimarronian "Red Beds" clothe the backslope of the Guadalupe Mountains and extend northeastward far into Kansas. There, and through the Panhandle of Texas, they are in turn overlaid by Triassic "Red Beds." The fact that a marked erosional unconformity separates the two terranes is a recent observation. To the northwest similar merging of "Red Beds" in continuous sequence obtains; and the Triassic Doloresian formation immediately succeeds Cimarronian deposits.

In New Mexico the strata of Triassic age are predominantly typical "Red Beds." There are two series of red shales and sandstones separated by an erosion interval. The earlier of the two series is confined to the east side of the Rockies, while the later one is represented chiefly on the west side of the Cordillera. Their total thickness is nearly 2,000 feet.

Like the Triassic sediments the Jurassic succession comprises an earlier and a later series, set off from each other by a great erosional unconformity. Together they represent a column 1,200 feet thick. The Morrisonian series is chiefly composed of argillaceous deposits. Of these the Chaquaqua (Chicago) shales occupy one-half of the entire section. They are underlaid by a basal sandstone. A notable erosion unconformity separates them from the succeeding Comanchan deposits.

When in the early fifties of the last century Jules Marcou, colleague and exiled compatriot of Louis Agassiz, fresh from the Jura Mountains, introduced into this country the European title "Jurassic" it was the Tucumcari section in eastern New Mexico that was involved. Around this Cerro Tucumcari raged a storm center for a full generation. After being overborne by sheer weight of numbers and after being submerged for seventy-five years Marcou finally comes into his own. Cerro Tucumcari proves to contain the full Jurassic section of the region. Marcou erred only in including some of the Dakotan sandstone layers.

The important Comanchan succession of Texas and the Gulf region finds but feeble representation in New Mexico, and then only as an attenuated border which soon vanishes completely against the Cordilleran uplift. The basal limestones of Texas are traceable around the Llano Estacado. The shales extend farther. Erosional unconformity separates its two series, and like sedimental breaks mark both top and bottom of the sequence. Because of the fact that the thin shale beds are immediately under the massive Dakotan sandstone they usually escape notice.

The basal Dakotan sandstone of the Cretaceous succession is especially noteworthy by reason of its very wide geographical distribution. In the Rocky Mountain region it is further remarkable because of its disposition on an old peneplain surface, which, although much deformed, now coincides with the tops of the highest peaks. Where the southern Rockies plunge in a triple fold

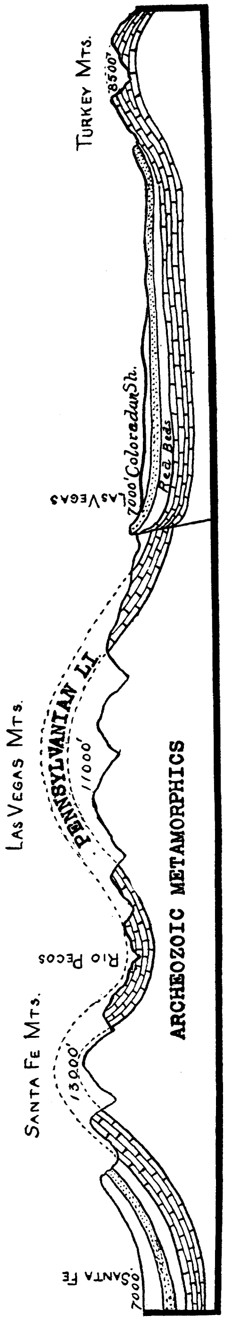

Fig. 6.—Ceja Glorietta: end of the Rocky Mountains

beneath the general plains' surface of the Mexican table-land the Dakotan sandstone forms a magnificent inward-facing escarpment. Along the steep interior face the Atchison, Topeka, & Santa Fe Railroad skirts for a distance of fifty miles. There, as elsewhere on the continent, the Dakotan sandstone is one of the geological landmarks of the region. With a thickness of 300 feet it is, perhaps, the most extensive basal sandstone of which we know (Fig. 6).

Immediately following the Dakotan sandstone is a fine succession of marine shales and limestones, which in New Mexico have a thickness of upward of 2,000 feet. This is the Coloradan series. A quite unusual feature is that the series preserves its subdivisional integrity through a distance of 1,000 miles, to Iowa and Minnesota, on the far side of the Continental Interior basin.

A succeeding 2,000 feet of strata comprising sandstones and shales constitute the Montanan series. It is an important coal-bearing formation, containing a larger fuel supply than do the coal measures of the entire Mississippi Valley. In early accounts of the region these coals were all regarded as Laramian in age. Locally the coal seams overlying the Ortiz laccolith are changed into high-grade anthracite, the quality of which compares favorably with the best hard coals of the Appalachians. East of the Rockies the Montanan beds merge into the marine Pierre shales.

As the uppermost member of the Cretaceous section the Laramian series embraces only a small part of the beds formerly paraded under this title. By divesting the old Laramie section of that portion which is really Tertiary in age the long drawn-out controversy concerning the true age of these beds comes to an abrupt end.

With the principal coal beds referred to the Montanan series below and the Ratonan series above the so-called Laramie formation of New Mexico becomes almost as barren as the marine Coloradan series. Still, in the northwestern part of the state, the Pictured Cliffs sanstones and the Navajo shales attain a thickness of nearly 1,200 feet.

Tertiary sedimentation in the New Mexican area begins with beds the deposition of which seem long to antedate the earliest Eocene formations of other parts of the world. When in the course of coal investigations in 1906 a marked erosional unconformity and basal conglomerate were found in the lofty Raton Mesa about 1,500 feet below its massive lava cap, it was surmised that the solution of the Laramie problem had been stumbled upon and that above the erosion plane the beds were really Tertiary in age, while those beneath that line were Cretaceous. These conclusions were fully substantiated a decade later by Lee in an elaborate monograph on the geology of the region.

The Ratonan series is, then, older than the oldest Eocene deposits of the state, the Puerco beds, which, since the days of Cope in the region, were believed to be the earliest Tertiaries extant. It is an important coal-bearing section, which fact probably largely accounts for its early confusion with the original Laramie coal formations of the more northern Rocky Mountains districts. The erosion plane upon which the Ratonan sediments rest is a peneplain of wide proportions evidently worn down on the entire southern Rocky Mountains province. In its production no less than a mile of rock was removed.

The Aztecan series is represented by a basal conglomerate of very considerable thickness. Beyond the borders of the state the Arculeta conglomerate is succeeded by shales. No sediments are correlated with the erosional interval below. It is possible that the basal unconformity is coextensive with the one beneath the Ratonan series on the opposite side of the Rockies, in which case the Arculeta and Maya formations are homotaxial. The term "Animas," which is sometimes applied to the beds of the San Juan basin is preoccupied.

In the Nacimientan series are included the basal beds of the old Wasatch group. It is regarded as earliest Eocene. It is subdivided into the Puerco clays and the Torrejon marls and sandstones. The deposits are doubtless entirely epeirotic in character and perhaps eolian. There is a large and varied vertebrate fauna. The outcrop constituted one of Cope's favorite collecting grounds. The beds have a maximum vertical measurement of 1,000 feet. Marked erosional unconformities separate all of the Tertiary terranes of the San Juan basin.

The Chaman series comprises the main body of clays, sands, and shales of the San Juan Wasatch succession. Canyon Largo sandstone is Newberry's early designation. Chaco terrane covers the principal clay deposits. Together they are nearly 2,000 feet thick.

Of manifest later date are the Tertiaries of the Rio Grande basin. These consist of the Galesteo sands and the Santa Fe marls, 1,300 feet in thickness. Over the Llano Estacado the latest Tertiary sands, 300 feet thick, are assigned to the Pecosian series.

The terranal names applied to the New Mexican Tertiaries cover only the main bodies of deposits. No doubt other titles will eventually be attached to the numerous minor members.

Quaternary deposits of New Mexico are chiefly desert concentrates. They are not mainly deflated materials, but accumulations left behind after the main bulk of fine rock débris has been sorted out and exported. The deflated dusts come to rest far outside of the arid region. Gravel and bowlder trains are principally the results of arroyo wash. Till-like materials are brought down from the highlands. Some glacial till yet remains on the sides of the highest mountains where ice fields were once feebly represented. Adobe soil is deflated dust temporarily at rest. Some fluviatile deposits are present. Lacustrine beds are rare, very limited, and quite ephemeral.

In the accompanying chart of New Mexican terranes the latter are fitted to the Chamberlin and Salisbury classification.

GENERAL GEOLOGICAL SECTION OF NEW MEXICO

Eras	Periods	Series	Terranes	Thickness in Feet	Rocks
Cenozoic	Present	Jornadan.....	....	25	Adobe
	Pleistocene ...	Palomasan....	....	200	Till
		Gilan.........	....	250	Gravels
			Interval......	....	Unconformity
	Pliocene......	Pecosian......	Llano E......	300	Sands
			Interval......	....	Unconformity
	Miocene......	Arriban......	Santa Fe.....	500	Clays
			Galesteo......	800	Sands
			Interval......	....	Unconformity
	Oligocene	Chaman......	Chaco........	1,000	Clays
			Canyon L....	700	Sandstones
			Interval......	....	Unconformity
	Eocene.......	Nacimientan..	Torrejon.....	300	Marls
			Interval......	....	Unconformity
			Puerco.......	500	Clays
			Interval......	....	Unconformity
		Aztecan......	Archuleta.....	250	Conglomerate
			Interval......	Great	Unconformity
	Arapahoe.....	Ratonan.....	Maxwell......	800	Shales
			Houten......	600	Sandstones
			Maya........	100	Conglomerate
			Interval......	Great	Unconformity
Mesozoic	Cretaceous....	Laramian.....	Navajo.......	1,000	Shales
			Pictured Cl...	150	Sandstones
			Interval......	....	Unconformity
		Montanan....	Lewis........	600	Shales
			Chacra.......	200	Sandstones
			Mesa Verde...	800	Shales
			Pina Vititos...	250	Sandstones
			Interval......	....	Unconformity
		Coloradan....	La Jara......	1,000	Shales
			Apishapa.....	500	Shales
			Timpas......	300	Limestones
			Gallinas......	200	Shales
		Dakotan.....	Glorietta.....	300	Sandstones
			Interval......	Great	Unconformity

GENERAL GEOLOGICAL SECTION OF NEW MEXICO—*Continued*

Eras	Periods	Series	Terranes	Thickness in Feet	Rocks
Mesozoic	Comanchan		Kiowa	100	Shales
			Garrett	50	Conglomerate
			Interval	....	Unconformity
			Washita	500	Limestones
			Fredericksburg	200	Limestones
	Jurassic	....	Interval	....	Unconformity
		Morrisonian	Chaquaqua	150	Shales
			Travester	100	Shales
			Exter	75	Sandstones
		....	Interval	....	Unconformity
		Zunian	McElmo	300	Shales
			La Plata	300	Sandstones
	Triassic	Doloresian	Wingate	900	Sandstones
			Le Roux	800	Shales
			Shinarump	600	Conglomerate
		....	Interval	....	Unconformity
		Dockuman	Trujillo	300	Shales
			Tecovas	200	Shales
			Interval	....	Unconformity
Paleozoic	Permian	Cimarronian	Quarterm	150	Shales
			Greer	125	Shales
			Chaves	425	Shales
			Interval	....	Unconformity
		Guadaloupan	Capitan	2,500	Limestones
			Eddy	1,000	Sandstones
			Interval	....	Unconformity
		Bernalillan	Torrance	500	Shales
			Yeso	600	Shales
			Manzano	500	Sandstones
			Interval	....	Unconformity
		Maderan	Tellera	300	Limestones
			Gallegos	100	Sandstones
			Antonito	200	Limestones
	Pennsylvanian	Lunasan	Mosca	200	Limestones
			Coyote	75	Sandstones
			Montosa	400	Limestones
			Sandia	250	Shales
			Interval	Great	Unconformity
		Ladronesian	Alamito	200	Shales

GENERAL GEOLOGICAL SECTION OF NEW MEXICO—*Continued*

Eras	Periods	Series	Terranes	Thickness in Feet	Rocks
PALEOZOIC	Mississippian	Tennessean	Interval	Great	Unconformity
		Socorran	Modoc	200	Limestones
			Sierra	50	Limestones
			Lake Valley	150	Limestones
			Grande	25	Limestones
		Waverlyan	Interval	Great	Unconformity
	Devonian	Martinian	Berenda	50	Limestones
			Interval		Unconformity
		Perchan	Bella	250	Shales
			Silver	200	Shales
			Interval		Unconformity
	Silurian	Santa Ritan	Interval		Wanting
			Naiad	250	Limestones
			Cibola	175	Limestones
			Interval		Unconformity
PALEOZOIC	Ordovician	Mimbresian	Cristobal	165	Limestones
		Montoyan	Frondosa	100	Limestones
		El Pasan	Armendaris	300	Limestones
			Interval		Unconformity
	Cambrian	Chiricahuan	Lone	300	Quartzites
		Chloridian	Carrasco	75	Limestones
		Dragoonan	Burro	500	Quartzites
			Hawkins	50	Limestones
			Mangas	100	Quartzites
			Interval	Great	Unconformity
PROTEROZOIC	Superorian	Valencian	Graphic	1,000	Lavas
			Sandoval		Granites
			Interval	Great	Unconformity
	Seikirkian	Albuquerquan	Ysidro	1,500	Shales
			Tijeras	250	Quartzites
			Interval		Unconformity
		Garnuan	Antonio	2,000	Shales
	Anian		Interval	Great	Unconformity

GENERAL GEOLOGICAL SECTION OF NEW MEXICO—*Continued*

Eras	Periods	Series	Terranes	Thickness in Feet	Rocks
ARCHEOZOIC		Pecurisan.....	Truchas......	900	Slates
			Penasco......	400	Quartzites
			Serna.........	1,500	Schists
			Interval......	Great	Unconformity
		Taosan........	Solitario......	800	Slates
			Rociada......	250	Limestones
			Sapello.......	300	Quartzites
			Ninos.........	1,000	Schists
			Interval......	Great	Unconformity
AZOIC	....	....	....	....	Slates Gneisses Schists

For general completeness the New Mexican rock-pile stands *facile princeps* among American geological sections. Being at once both a critical and a standard terranal succession for the continent, it merits and invites closest inspection, carefulest evaluation, and widest comparison. It reflects regional crustal movements along a primitive continental plait more directly and more perfectly than perhaps any other known section. Amplitude of diastrophic oscillation is sufficiently large and sharp to make this a direct basis of genetic taxonomy. It admits of orotaxial classification of geological formations at its best.